Human – Robot Coordination For Multi – Sized Humanoid Robot Using Wireless Communication

K. Shyam Ravi Shanker, C. Mala, N.P.Gopalan, K. Anuja and V. Sridevi

***Abstract*—To aid people working in hazardous situations such as defense, military and for those pursuing research, a robot based on replication technique capable of performing any task and which can be controlled via wireless link is proposed in this paper. These robots will be of immense use in such situations as they can don the roles of human beings. It has extensive monitoring and maneuvering capability attainable at a low driving voltage and has a good response to external stimuli. This paper presents the methods for making the robot's motion to be in congruence with that of the human being who operates it, obviating the need for sensors. An efficient design of cost effective robots of various sizes which can be interfaced with a single Teaching Hand Gripper (THG) designed specifically for the joints of the human for their operation has also been proposed. The THG is calibrated to overcome the discrepancies among potentiometers used for robot motion. The performance of the proposed system is tested on a robot with a single joint and the results are presented for a simple closed loop system. The robot is given fast, medium and slow responses as inputs such that a variation of 30 degrees is achieved in time intervals of 1, 2 and 3 sec. The output lag and the system efficiency are analyzed. The distance between the robot and the point of control can be up to 75km. The control signals are transmitted from the human to the robot via FM. These robots when under use in a hazardous situation can be efficiently operated from a safe environment.**

***Index Terms*— Automation, Control. FM, Intelligent, Programming, Robot, System.**

I. Introduction

The control of conventional button operated robot can be achieved by alternatives like voice & physical motion [1, 7, and 8]. The usage of body movement to activate humanoid robots is in vogue and generally expensive due to sensors used in them [9]. Programming by human demonstration is an intuitive method of robot programming [2], in which the programmer demonstrates how a task is performed using a THG that measures human motion, and the data gathered is used to generate the robot program. In the existing approaches a direct duplication of the demonstrated trajectory would result in unsatisfactory robot motion due to human "wiggles" and unnecessary motion in case you use sensors [1, 2]. In this paper the human inconsistency is treated as noise that is eliminated by the use of potentiometer and analog to digital converters with lower resolution compared to that of the sensor. The proposed work deals with humanoid robots, which depend on the calibration, fault tolerance, control system and rotational dynamics at each joint for its motion [3, 4]. Non -specification of starting reference point at any instant of time after resumption from a power failure is the most salient feature of this present study [2]. The concept of safe activation of robots of different sizes with a single THG by the use of low voltage is another desirable feature of the proposed work. By using this proposal even a person who doesn't possess knowledge of computers will be at ease in programming the robot depending on the situation. An efficient design of robots of various sizes which can be interfaced with a single THG is also an impressive feature of the robot. The number of potentiometers required for the THG and robot is given by 2n, where n is the number of joints either in the robot or in the THG.

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II. Proposed Work

Physical motion stems from the angular movement arising at the various joints in our body. Hence the measure of rotational motion at the joints of the demonstrator body is essential for replication by the robot. The Architecture of the robot and the THG plays an important role in the control of the robot [9, 10]. The angular displacement at the joints of the demonstrator gripper is measured with the help of a rotary potentiometer which also serves as an indicator of angular displacement. The exact positioning of the potentiometer is made on the robot, such that the potential variation in both the demonstrator gripper potentiometer and the robot potentiometer are identical as shown in Fig.1. The congruent motion of the robot and THG is due to the presence of simple closed loop system at each joint of the robot as shown in Fig.2.

The position of the robot can be determined from the potentiometer reading from all the joints. A camera attached to the top of the task robot captures the images of the objects and transfers them to the destination which in turn guides the robot to perform the desired task [5, 7]. The images are transferred to the destination by using data acquisition tool in Mat Lab. The potentiometers and motors are mounted in such a way that the variation in the demonstrator setup has an impact on the robot setup resulting in the matching of positions.

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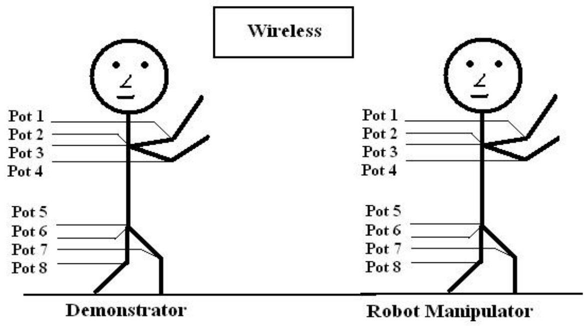

Fig.1 Arrangement of potentiometer

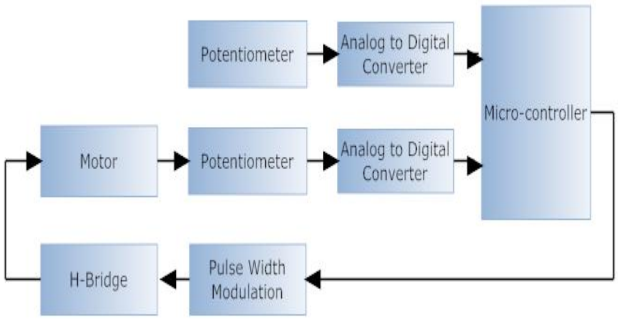

Fig.2 Simple closed loop system

III. WORKING PRINCIPLE

A. Closed Loop System for replication process

The development of control systems for robot manipulators with redundant kinematics is still a demanding task [3, 4, and 11]. This task becomes even more challenging if the robots to be controlled operates in partly unknown environments which vary over time and may be thousands of kilometers away from the operator, for example in space. The motor is connected with the potentiometer, thus causing the potentiometer to rotate and correct the error, resulting in least possible error. Depending on the error the input to the motor applied is decided by an H- Bridge circuit, to either rotate clockwise or anti-clockwise as shown in Fig.3. If the error is positive, positive potential is applied to the motor which overcomes the error with a positive correction, hence rotating the motor in clockwise direction. If the error is negative, negative potential is applied to the motor which corrects the error with a negative correction, thereby rotating the motor in counter clockwise direction. The equation to compute error is given by

$$E(s) = C(s) - R(s) \qquad (1)$$

E(s) – Error
C(s) – Input to the system
R(s) – Output from the system

To avoid steady state error and for the error to be zero, the motor speed is varied when the position of the robot is nearer to the THG position. When the difference in position of the robot and the THG is less than 15^o, the motor speed is reduced to one half of the original speed by the use of Pulse Width Modulation. When the difference in position of the robot and the THG is less than 7^o, the motor speed is reduced to a quarter of the original speed. The algorithm for operation is as shown in Fig.4.

B. Multi-Sized Robot matching with a single designed demonstrator gripper

Condition for the robot to replicate the action performed in THG at each joint is

$$\theta(s) = \varphi(s)$$

Where θ and φ is the angle moved by the THG and the robot respectively.

To have a clear idea about the concept, a humanoid robot is taken for reference and illustrated. The condition for a robot of any size to replicate the action performed in the gripper at each joint is

$$\theta(s) = \alpha\, \varphi(s)$$

Where α is a constant.

If α>1, Variation of the potentiometer in the THG is greater than that of the robot potentiometer as shown in Fig. 5

If α<1, Variation of the potentiometer in the robot is greater than that of the THG potentiometer as shown in Fig. 6

If α=1, Variation of the potentiometer in the robot is same as that of the THG potentiometer as shown in Fig. 1

While using different dimensions of robot and THG, the robot cannot replicate the action because the variation of the potentiometer at the joint is dependent on the size of the potentiometer used in the robot and THG. Any multi-sized robot replicates the actions of the THG by means of the potentiometer installed which helps in defining a factor and nullify the effect of the variation.

In a transmitter, the factor is defined by the user with the potentiometer as shown in Fig.8 and the factor is multiplied so that the data received in the receiver will be in accordance with the dimensions of the THG as shown in Fig.7. Assumption is made that all the potentiometers at the joints of the robot and the THG vary by the same factor.

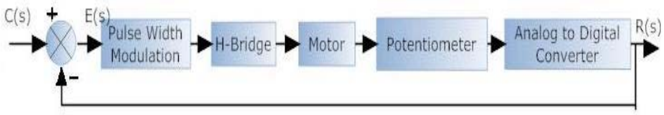

Fig.3 Simple closed loop in frequency domain

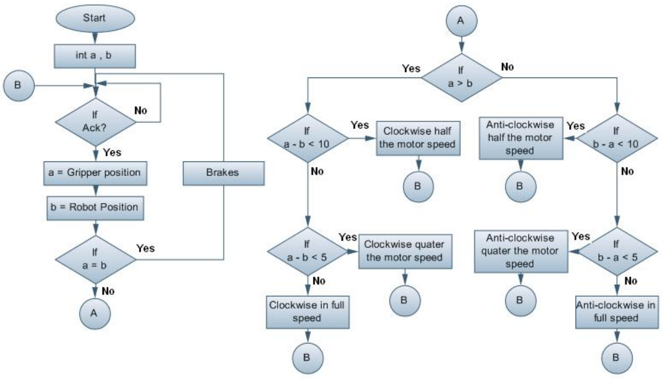

Fig.4 Micro-Controller A Algorithm

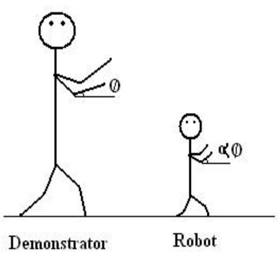

Fig.5 For α>1

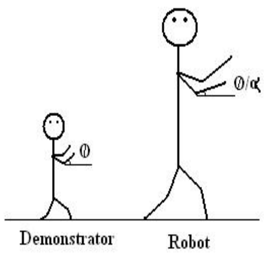

Fig.6 For α<1

Fig.7 Multi–sized robot coordination by adjusting α

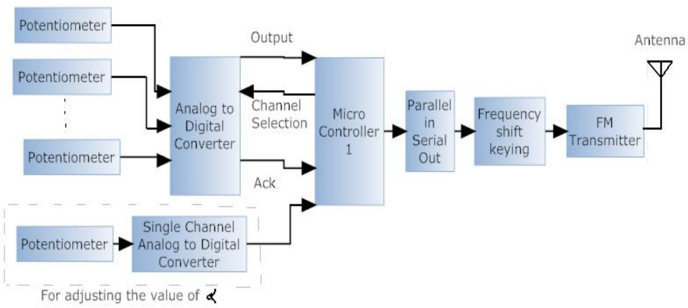

Fig.8 Wireless Transmitter

IV. USING WIRELESS COMMUNICATION

A. Demonstrator Gripper Circuit

The THG circuit using wired communication is shown in the Fig.8. The algorithm for microcontroller 1 in the transmitter is shown in Fig.9. The potentiometer rotates up to 320 degrees but no joint in our body has the capacity to rotate more than 270 degrees. So a value is assigned for acknowledgement of cycle completion such that any loss of data will be corrected by the new data received in the next cycle as shown in Fig.12. The output decimal value of 255 is assigned for acknowledgement of completion of one cycle. When the value of 255 is obtained at the receiver side, the next data transmitted will be considered as new cycle. Before the pulses are given as input to the FSK modulator, it must be converted to serial data which is achieved with the help of the shift register.The Frequency shift Keying(FSK Digital modulation technique) circuitry is used for converting the digital pulse to analog output to be fed into the FM transmitter. In the FM transmitter is an analog modulation technique hence requires analog input which is achieved with the help of FSK modulator. The output from the FSK will be fed as input to the FM Transmitter, where Microphone is replaced by the FSK modulated waveform

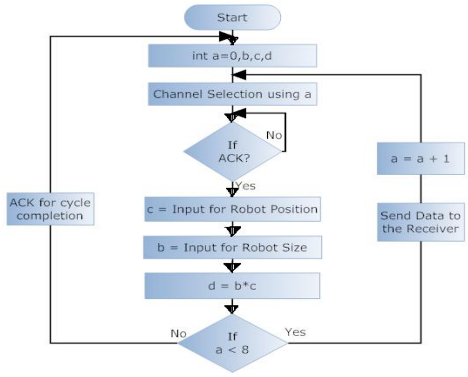

Fig.9 Algorithm for microcontroller 1

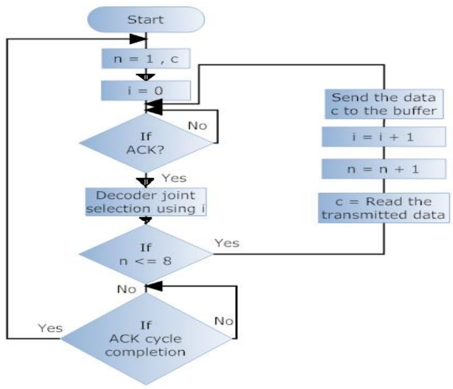

Fig.10 Algorithm for microcontroller 2

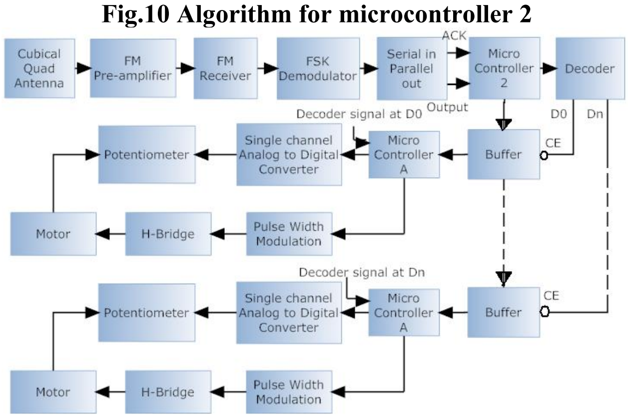

Fig.11 Wireless Receiver

B. *Receiver*

The block diagram for the circuit in the fish-like robot using wireless communication is shown in Fig.11. The algorithm for microcontroller 2 and microcontroller A in the receiver are shown in Fig.10 and Fig.4 respectively. At the receiver end, mounting a small size antenna would make the architecture of the robot stable. To have a better efficiency in mind Cubical Quad type antenna is chosen for FM receiver .The FM preamplifier act as an amplifier that amplifies the signal before data processing. The FSK Demodulator is used for converting analog output from the FM Receiver to digital data. The microcontroller is connected to the decoder to select only one buffer at a time. All the buffers are given parallel connection to the output port of the microcontroller 1, so that it will enable the data to reach only a particular joint. The chip enable pin of the buffer helps to correlate the data from the demonstrator setup to the corresponding joint of the robot. The FM transmitter of 2W is constructed and tested at various distance from the operating point. The serial in parallel out helps to make data processing easier by sending parallel data to the microcontroller. The FM transmitter that can send the signal up to 2km can be received from a distance of 75km by using the Pre – amplifier designed with Dual Gate MOSFET. Dual Gate MOSFET pre – amplifier circuit has much higher gain approaching that of the vacuum and having high signal to noise ratio. Dual Gate MOSFET Pre – amplifier circuit designed gives an excellent gain of about 18dB.

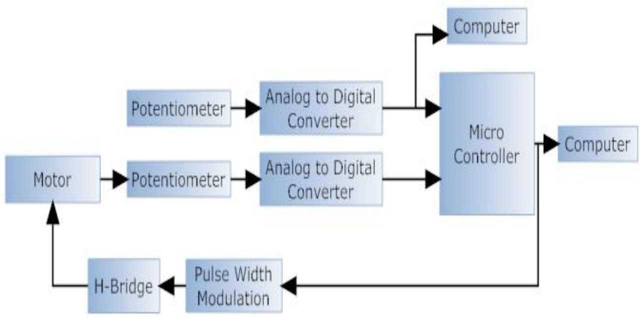

Fig.12 Closed loop system

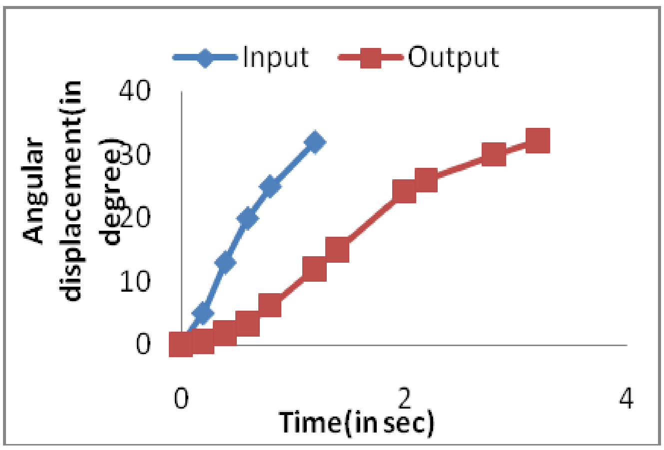

Fig.13 Time vs. Displacement in 1 sec

V. Applications

The proposed model will be of immense use in the following applications:

1. The design proposed is compatible for robots such as humanoid robots, fish-like robots and quadrupled robots.

2. Obviate human intervention to search and defuse bombs in hazardous situations.

3. Exploration of planets, moon and dangerous forests.
4. Autonomous design using THG for programming humanoid robots.
5. Help the old in carrying out certain tasks which may have become onerous as result of their advanced age.

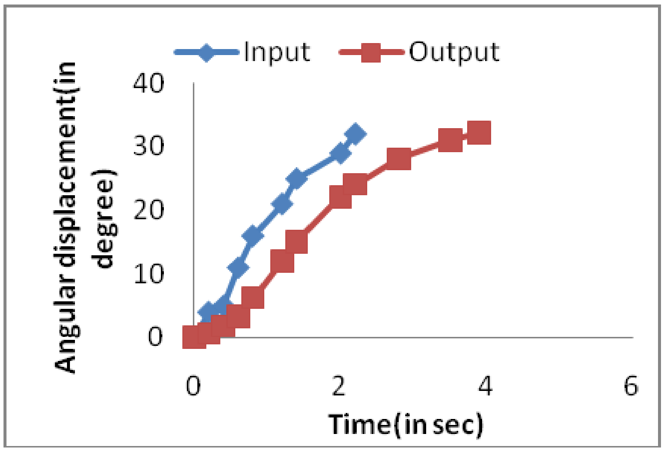

Fig.14 Time vs. Displacement in 2 sec

VI. Performance Analysis

A closed loop control system as in Fig.12 is used for performance analysis. The parameters used for analyzing the performance of the robot are position, time, angular displacement, velocity, efficiency, propulsion force [2, 6]. For our present study, parameters such as time, frequency, angular displacement, angular displacement lag, efficiency, velocity, displacement and propelling speed are considered. Practical testing introduces a variation of 1.4 degrees which will cause the input of the micro controller to change by one decimal or one hexadecimal. So the variation in the position is determined by the values got as input from the computer and the decimal is converted in terms of degrees.

In Fig.16 to 18, the robot is tested by slow, medium and fast responses as inputs such that a variation of 30 degrees is achieved in time intervals of 1, 2 and 3seconds. The robot's performance is analyzed under three different scenarios in which input applied can be categorized as Slow, Medium, and Fast.

Scenario 1: Input is applied slowly: This is applicable in situations where the robot is used for performing surgery or defusing a bomb where high accuracy is required to prevent accidents. In such cases the input to the robot should be applied slowly as shown in Fig. 15.

Scenario 2: Input is applied at a medium rate: If the robot is to be used for carrying light weight objects and to perform tasks relatively fast, the variation in the input applied should be medium as in Fig. 14 to enable the robot to carry the load.

Scenario 3: Input is applied fast: If the robot is to walk and climb stairs within a short span of time, the input is to be applied fast as shown in Fig. 13 to get the expected performance.

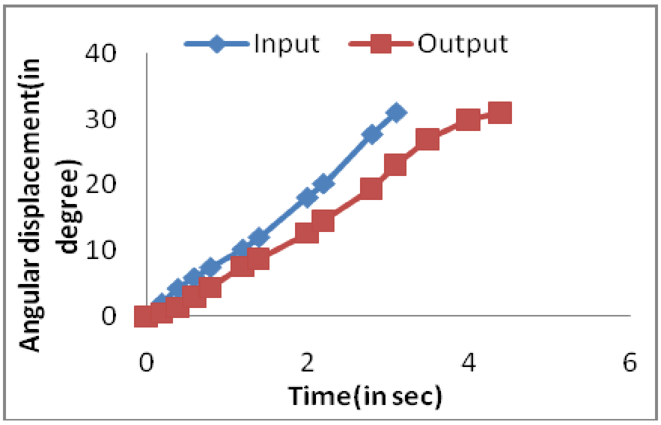

Fig.15 Time vs. Displacement in 3 sec

The efficiency of the robot under the above mentioned scenarios is experimented and the values noted are plotted in Fig. 16. The efficiency reduces with increase in the rate at which the input is applied to the robot.

Further, for the robot used, the lag which is the time taken by the robot to respond to the given input is also measured under the three different scenarios mentioned above and the results are plotted in Fig. 17. It can be seen that the lag of the robot is minimum if the input is applied slowly and the lag increases as the rate at which the input is given also increases. The steady state error, oscillation before settling in a position is found to be nil at the mentioned testing conditions.

The robot and the THG are tested at various distances, and the robot is able to operate in accordance with the THG for a range of 75Km with a transmitter power rating of 2W. By varying the value of α, multi-sized human-robot coordination is made possible and successful working with very minute error is obtained. Because of the declaration of α as integer as shown in Fig.9, the percentage error ranges from 0.00392% to 0.388%. For the value of α to be in the range 0 to 2, the resolution was found to be 0.0156 and for a range of 0 to 10, the resolution was found to be 0.0833. To have higher resolution and accuracy, lesser range of values of α should be used.

VII. Conclusion

A humanoid robot which can be operated by physical movement of the demonstrator using wireless communication is designed and tested. From the experimental results, it is shown that efficiency of the robot can be varied by changing the input response given by the THG. At low input response, the efficiency was found to be the highest with negligible lag. Thus by varying the input the efficiency can be varied. The steady state error of the robot while settling in a position was found to be nil. This concept can be extended to an autonomous robot by programming it accordingly.

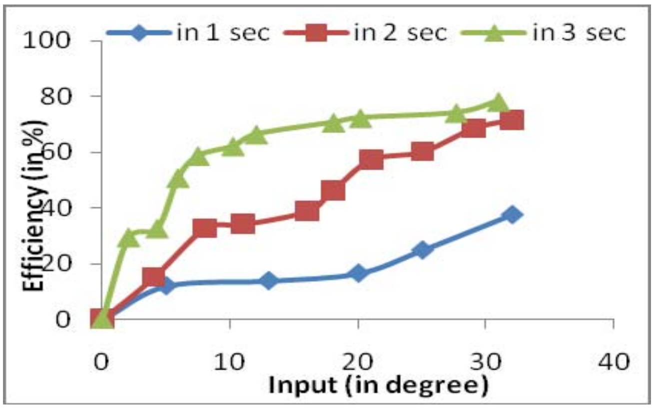

Fig.16 Efficiency vs. Time

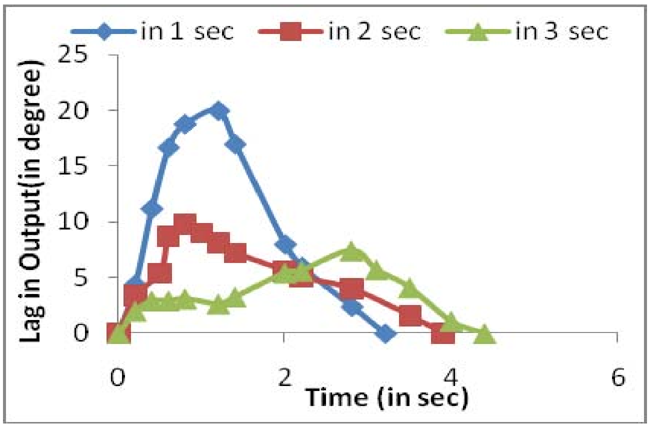

Fig.17 Lag in output vs. Time

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